THURSDAY, MARCH 29, 1906.

STARS AND NEBULÆ.

The System of the Stars. By Agnes M. Clerke. Second edition. Pp. xvi+403. (London: A. and C. Black, 1905.) Price 20*s*. net.

THERE is much excellent sense in the French proverb, "Prends le premier conseil d'une femme, et non le second," which expresses the view that the intuitive instinct of a woman is a safer guide to follow than her reasoning faculties; and although in these days it is considered ungracious to make this suggestion, evidence of its truth is not difficult to discover in most literary products of the feminine mind. It is no disparagement to Miss Clerke to say that even she shares this characteristic of her sex, so that sometimes she lets her sympathies limit her range of vision in the field of stellar research. No doubt this disposition is exercised unconsciously, but what is an attractive instinct when applied to ordinary affairs of life is derogatory when it influences the historiographic consideration of contributions to natural knowledge.

There are many students of science who follow the trend of a writer like Miss Clerke with lamb-like sequacity, and consider it almost a presumption to express any dissatisfaction with her presentment or interpretation of scientific fact. It is a sign of weakness to occupy a position of this kind; and particularly so when the author whose views are accepted is not actively engaged in the investigation of the field surveyed. Science is not a persuasion in which personal opinion has to be respected whatever the value of the material evidence in its support. We may admire Miss Clerke's literary skill and be impressed by the brilliant periods in which she frequently encloses simple matters of fact, but, at the same time, we may be permitted to recollect that she is a bibliographer rather than an observer, and therefore her works, be they never so distinguished as literature, need only be regarded as narratives by a spectator, when the weights of the results and conclusions recorded in them are being decided. There is, as Francis Bacon knew, a vast difference between opinions based upon the study of books and papers and those derived from individual observation and experience. "Studies themselves doe give forth Directions too much at Large, except they be bounded in by experience. Crafty Men Contemme Studies; Simple Men admire them; And Wise Men Use them. For they teach not their own Use; But that is a Wisdome without them and above them, won by Observation."

This statement of Miss Clerke's position is necessary by way of excuse for the temerity of a reviewer who ventures to criticise some points in a work of such a substantial character as the present one. The book has been revised so completely that scarcely a page of it remains the same as in the original edition published fifteen years ago. In this period much new work has been accomplished, and from it Miss Clerke has selected what she considers to mark essential steps in the progress of sidereal science, to incorporate with the results previously described. The task of sidereal astronomy was formerly stated to be the investigation of "the nature, origin and relationships of sixty million stars and upwards of eight thousand nebulæ," but the numbers are now "30,000,000 stars and 120,000 nebulæ." The discovery of terrestrial helium has led to the recognition of a new stellar type having helium rays prominent in their spectra, while oxygen, silicon, and titanium are among other substances the rays of which have been identified in celestial bodies in recent years. Numerous stars have been proved by the spectroscope to be close couples; and "Prof. Campbell showed in 1902 that, among the entire multitude of stars, one in six or seven is so constituted." From spectroscopic observations, it has also been possible to determine that the solar system is moving toward an apex in right ascension 277° 30′ and declination +20° at the rate of 12½ miles a second, the probable error of the result being less than one mile a second. The demonstration of the motion of nebulæ in the line of sight has shown that there is no difference in this respect between nebulæ and stars, and has thus removed a difficulty formerly offered to the view that stars arise from a condensation of nebulous matter. Finally, the large number of variable stars found in certain globular clusters, the phenomena presented by such temporary stars as Nova Aurigæ and Nova Persei, and the structure and distribution of nebulæ in relation to the Milky Way, can only be simply and sufficiently explained by the existence in space of clouds of obscure particles alone or associated with luminous matter. The most noteworthy discoveries of astronomical science in recent years are, indeed, those which demonstrate or suggest that space may include as much dark material as bright.

Until a few years ago it was believed that nebulæ are masses of glowing gas at a high temperature; but Miss Clerke is now able to write, "experience is wholly contradictory of the notion that nebulæ are excessively hot bodies." It is scarcely too much to say that the evidence brought forward by Sir Norman Lockyer in connection with his meteoritic hypothesis of celestial evolution is chiefly responsible for the change of view that has taken place. An astronomer unfamiliar with the literature of astrophysics would not, however, derive this impression from the study of any parts of this book in which nebulæ are dealt with. Again, it is stated that a consensus of opinion regards gaseous nebulæ as being "luminous through electrical excitement"; but though this is frequently mentioned, there is no record of the suggestion made in 1888, as the result of spectroscopic examinations of meteorites, that in the Orion nebula "the hydrogen is electrically excited"; yet this observation was recorded in the original edition of Miss Clerke's book.

The low temperature of nebulæ, electrical excitation as a cause of luminosity, and the suggestion that the apparently continuous spectrum of white nebulæ, like the nebula of Andromeda, would prove to be an interrupted band of colour, are all functions of the meteoritic hypothesis. These three points have been specifically and repeatedly mentioned in connection with the hypothesis, as, for instance, in the remark that the general absence of bright lines of metallic vapours, and of the bright lines of hydrogen in white nebulæ "evidently justifies the conclusion that we are here in presence of those bodies in celestial space, the temperature and the electrical excitation of which are at a minimum, and as the continuous part of the spectrum is brought under examination further stages will be recognised. . . . There can be little doubt that when our instrumental appliances and observing conditions become more perfect, it will be found that the so-called continuous spectra will be a perfect mine of new knowledge regarding the true nature of the changes which occur as condensation increases" ("Meteoritic Hypothesis," pp. 323, 324).

This was written sixteen years ago; and the work that has since been done enables Miss Clerke to arrive at the same conclusions, though she has forgotten the observations which have changed the position formerly occupied. She can now write:—

> "Gaseous nebulæ are, in fact, reasonably believed to be at a temperature not much above absolute zero. They are not, then, incandescent, but rather 'luminescent'; their light is independent of thermal conditions."

Also we find in several places the view accepted that even the spectra of white nebulæ are not truly continuous, but show

> "slight inequalities in the flow of light, indicating effects of absorption, of emission, or of both combined."

In the present state of knowledge of nebular spectroscopy, no opinion of substantial value can be expressed as to the relationship existing between nebulæ exhibiting the characteristic line at λ 5007 alone or with other lines, and nebulæ with apparently continuous spectra, but the view that the difference is due to different degrees of condensation of congeries of meteoritic matter—cosmic dust—the Andromeda type of nebula being in a more condensed condition than an irregular nebula like that of Orion, is at least as reasonable as any other. Even if this suggestion is considered to be of negligible value, there remains the fact that the present tendency is to regard the spectra of all nebulæ as being really discontinuous, as was anticipated in the meteoritic hypothesis. Moreover, Miss Clerke admits that, apart from the question of the apparent differences between the two spectroscopic types of nebulæ,

> "relationship between the various orders of nebulæ is manifest. The tendency of all to assume spiral forms demonstrates, in itself, their close affinity; so that to admit some to membership of the sidereal system while excluding others would be a palpable absurdity. And since those of a gaseous constitution must be so admitted, the rest follow inevitably."

It is not clear from this, or from other remarks in the book, how we are to regard the white nebulæ, if only as a working hypothesis. Most spiral nebulæ do not give the characteristic spectrum of hydrogen and helium, yet it is agreed that all spiral forms are closely related. If it is assumed that the spiral nebulæ with bright line spectra are entirely gaseous in constitution, it is difficult to explain the existence of apparent "stars," presumably at a higher temperature than that of the general mass of gas, threaded upon the spirals. If, however, the view is accepted that the luminous radiations of so-called "gaseous" nebulæ are really only the visible manifestations of electric or dynamic disturbances of a mass of cosmic dust—and few would now deny the existence of dark matter in nebulæ—the explanation of spiral nebulæ is easy, and the difficulty as to the relationship between these nebulæ and others disappears. The existence of streams, sheets, and shells of palpable matter intersecting at various points is sufficient to account for the bright portions of spiral nebulæ with the apparent stars arranged along the spirals; if nebulæ have this meteoritic constitution spiral forms ought to predominate, as they actually do. Spiral nebulæ like those of Andromeda and Canes Venatici are certainly not purely gaseous in constitution, though a few years ago it was more necessary to insist upon their non-gaseous nature than it is now; but while we await crucial observations to decide how nebulæ of different spectroscopic types are related, Miss Clerke might have shown that an explanation has been given, though she may disapprove of it.

A knowledge of the constitution of nebulæ is of fundamental importance, for upon it must be based any satisfactory scheme of evolution of celestial species. All astronomers accept the idea of evolution from nebulæ, but as to the order of development, and the means by which it is brought about, no hypothesis has met with general adoption, even as a working principle. A common ground of agreement, however, is that nebulæ showing the characteristic trio of lines—λλ 4860, 4950, and 5007—in their spectra are at a relatively low temperature. Given the cosmical amœba in the form of a nebula, what will become of it? The question cannot be answered directly, because sidereal ontogeny transcends human experience; but though the development of the individual nebula cannot be followed, a sidereal phylogeny can be based upon the spectroscopic characters of celestial species. Miss Clerke does not deal with nebular and stellar spectra from the point of view of development; for she takes Secchi's four types of spectra as her groups for discussion, and only makes incidental reference to the stages occupied by particular stars in an evolutionary scheme. The helium-stars, typified by certain stars in the constellation Orion, are regarded as the first results of condensation from nebulæ; Sirian stars represent the next stage, and then the solar condition is reached.

> "In a general sense it may indeed be said that the spectra of the sun and of solar stars imply a state of things in their reversing layers analogous to that prevailing in the arc-light, while in helium and Sirian stars the conditions of the spark are more nearly reproduced."

From stars of the solar type, Miss Clerke suggests that the development is toward the condition of Betelgeux, which exhibits the Fraunhofer spectrum in association with titanium flutings or bands, then to α Herculis, in which "the bands have acquired strength through the efflux of time, it is supposed, and the progress of cooling." Further than this she does not go, Secchi's fourth type of stars, showing absorption flutings of carbon in their spectra, being regarded as a class apart, and not united to the sun and its congeners in an evolutionary series.

In this classification of stellar spectra, temperature is not considered as an essential factor or a concomitant of the changes described; the question of the temperatures of the stars forms the subject of a separate chapter, new to the present edition. Heat is not entirely discarded, but "luminescence," "radiology," and "electrical excitement" now appeal to Miss Clerke's affections, and she flirts with them whenever she has the opportunity, though little is known of their resources. By this course she is able to believe, with Sir William and Lady Huggins, that solar stars are hotter than Sirian stars, while she acknowledges, as has been shown, that arc-lines are characteristic of the former type of spectra and spark-lines of the latter. Whether the temperature of the electric spark is actually higher than that of the arc has yet to be decided, but solar stars can only be placed at a higher temperature-level than white stars by neglecting much circumstantial evidence in support of the superiority of the spark. As a matter of fact, laboratory observations, so far as they are available, show that the same spectra can be produced by thermal or electrical action. Under conditions from which electrical influences were probably excluded, and the spectra obtained were due solely to high temperature, nitrogen at temperatures above 3000° C. has been found to give an emission spectrum in which the principal lines characteristic of the element were visible (Nasini and Anderlini, *Atti dei Lincei*, July, 1904). The agency by which gases and vapours are rendered incandescent seems, indeed, to be inconsequential, and high temperature is probably competent to produce the same spectroscopic results as those observed when incandescence is caused by the oscillatory discharge.

Electric and thermal effects cannot, however, be distinguished from one another in stellar spectra; therefore any attempt at a temperature classification must provide for possible electric influences. It was recognised by Sir Norman Lockyer more than thirty years ago (Roy. Soc. Proc., vol. xxii., p. 372, section ii., June, 1874) that the action of electricity must be included in the term "temperature"; and while the chemical changes effected by thermal and electric forms of energy cannot be discriminated in celestial spectra, the aim should be to construct a chemical classification without waiting for a complete understanding of the active causes of atomic vibrations or molecular combinations revealed by the spectroscope.

From whatever point of view stellar spectra are studied, little support can be found for the conclusion that the solar stars are at a higher temperature-level than the white stars. From a comparison of the spectra of Capella and Vega—typical solar and white stars respectively—Sir William and Lady Huggins concluded that "The solar orb seemed intrinsically the *bluer*, and was inferred to be the hotter of the two"; but neither the observation nor the inference can be regarded as established. Adopting the relative length of the ultra-violet spectrum as a criterion of stellar temperature, observations show that solar stars are really weaker in ultra-violet rays than white stars. In a paper on "Radiation through a Foggy Atmosphere" (*Astrophysical Journal*, vol. xxi., No. 1, January, 1905) Prof. Schuster accepts "the comparative weakness of the ultra-violet radiation in solar stars" as a fundamental fact which he attributes to molecular scattering in the photospheric regions of these bodies; but whatever the explanation, it is clear that spectroscopists have not adopted Sir William and Lady Huggins's view as to the ultra-violet spectrum of solar stars, but hold an opinion directly opposed to it. The extension of spectra into the ultra-violet may be regarded as the result of increased temperature, but by this standard white stars are placed above solar stars, and not below them.

All standards of comparison should, however, lead to the same spectroscopic succession if they are true tests of evolutionary development of celestial species. The sequence derived from comparisons of the lengths of ultra-violet spectra is the same as that revealed by the presence of gaseous and metallic lines of helium and hydrogen, and the enhanced and arc lines of the metals. In stars which have relatively the longest ultra-violet spectra there are few absorption lines; iron is represented practically by the enhanced lines alone, and the lines characteristic of the arc spectrum are almost or entirely absent. Only by considering the length of the ultra-violet spectrum together with the presence or absence of iron lines and lines that are intensified in passing from the condition of the arc to that of the spark can a useful classification of stellar spectra be established. When this principle is adopted a chemical classification of spectra becomes possible, and a reasonable scale of stellar thermotics is arrived at. From a hot star like Bellatrix a descending series can be arranged through β Persei, γ Lyræ, Sirius, Castor, and Procyon to Arcturus—a relatively cool star—by considering the changes in the spectrum of any constituent in passing from one grade to another. A continuous ascending series of spectra reaching up to Bellatrix can also be arranged from the spectrum of nebulæ of the Orion type through planetary nebulæ and the Wolf Rayet stars showing the line λ 4688 in their spectra to Orion stars in which this line is dark. This arrangement of spectra corresponds also with the sequence which would be expected as the result of various degrees of chemical dissociation at different temperatures. Stars having the smallest number of chemical elements represented in their spectra are probably the hottest, while an increased number of lines in other spectra is probably due to the existence of an increased number of chemical elements as the result of lower temperatures, the inferior position on the temperature scale being indicated also by the reduction of the relative length of the spectrum, increase of the relative intensity of red radiation and general absence of enhanced lines. Little is said about this chemical classification by Miss Clerke, and nothing in its favour, yet it represents the conclusions of a lifetime devoted to the study of spectra in the laboratory and observatory, and abundant material relating to it appears in the Proceedings of the Royal Society. Anyone unfamiliar with this material who reads what Miss Clerke has to say upon the temperatures of the stars and the interpretation of stellar spectra would have an inadequate idea of the results of systematic studies of these subjects, or of the existence of substantial ground of appeal against her verdict.

An instance of an incomplete statement that tends to mislead the reader is afforded by the note on Sir William and Lady Huggins's experiments on the behaviour of the H and K lines of the spectrum of calcium (Roy. Soc., June 17, 1897). By reducing the density of calcium vapour the lines H and K were obtained alone, and it was concluded that the various appearances of calcium lines in celestial bodies were due to the different states of density of the gases from which the lines were emitted or absorbed, and not to degrees of dissociation. The H and K lines in the solar spectrum are considered to prove the existence of "the metal calcium in a highly rarefied state"; and upon this evidence, referring to the condition of this element, Miss Clerke remarks:—"The hypothesis of its dissociation in the sun thus remains unverified." As a matter of logic, the experiments only prove that the H and K lines of calcium are spectroscopically persistent, and were able to survive (as might have been expected) conditions which effaced weaker lines in the spectrum of the element. Because brachiopods belonging to the genus Lingula are found in the sea at the present day as they were in Palæozoic ages, while many other forms that were contemporary have disappeared, we do not conclude that organic evolution is impossible, but only that the organism represents a type which persists in spite of changes of conditions. In the same way the continued existence of the H and K lines affords no evidence whatever against the view that there are different molecular groupings of calcium at different temperatures. By reducing the density of the calcium vapour, Sir William and Lady Huggins reduced the quantity acted upon; so the dissociated condition represented by the appearance of H and K alone was reached sooner. Similar experiments were made by Sir Norman Lockyer in 1879, and the conclusion arrived at was that a reduction in the quantity of a substance generally simplifies the spectrum. "In all probability the effects hitherto ascribed to quantity have been due to the presence of the molecular groupings of greater complexity. The more there is to dissociate, the more time is required to run through the series, and the better the first stages are seen" (Roy. Soc. Proc., vol. xxx., p. 26).

It will be seen, therefore, that the principal point of Sir William and Lady Huggins' experiment on calcium vapour at different densities was the subject of laboratory experiments more than twenty years earlier, and that their conclusion, though it is mentioned by Miss Clerke without reservation or reference to previous investigations, is not a safe one to apply to the consideration of the condition of calcium in the sun or stars as indicated by spectroscopic appearance. Moreover, if the changes of the calcium spectrum are interpreted as effects of tenuity, the similar spectral variations of magnesium and iron ought to admit of a like explanation, whereas there is good evidence that they are due to constitutional changes brought about by thermal or electric action.

Many other debatable matters are dealt with by Miss Clerke in a manner which suggests that the last word has been said upon them when she is really only presenting one side of a case. It may be assumed that, like a good advocate, she is as familiar with the defendant's case as she is with the plaintiff's, but the real strength of the evidence opposed to the views she adopts could only be shown by the disciple of another school of spectroscopy; and a small volume would be required to plead this cause. No writer on astronomy has a more facile pen than has Miss Clerke, and we can forgive the occasional florid style when we remember the vast amount of reading and careful analysis involved in the preparation of a volume of this kind. The work is so good that every student of astronomical physics must be familiar with it, and every astronomical library must include it. Because of its essential qualities it is to be regretted that a broad view has not been taken of all contributions to the subject made by competent investigators; for by neglecting such aspects as have been referred to in the foregoing paragraphs an incomplete story is presented of the meaning and mysteries of sidereal development revealed by spectroscopic research.

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BRITISH ASCIDIANS.

The British Tunicata: an Unfinished Monograph. By the late Joshua Alder and the late Albany Hancock. Edited by John Hopkinson, with a History of the Work by the Rev. A. M. Norman, F.R.S., &c. Vol. i. Pp. xvi+146+xx plates. (London: Printed for the Ray Society, 1905.) Price 12*s.* 6*d.* net.

THERE are probably few precedents for the publication of an unfinished biological monograph thirty years after the authors penned their last remarks, especially of a monograph dealing with a group which has been the object of much detailed investigation by other hands in the interval. The chequered history of the present work is briefly, but sympathetically, told by Canon Norman, from whose preface the following paragraph may be extracted:—

> "Though so many years have elapsed, the value of this Monograph is great, since (1st) it contains full descriptions with illustrations of the Tunicata of our fauna as known up to the time of the death of the authors; (2nd) because many of the new species had been only briefly diagnosed, and the fuller descriptions and figures of these which are now given will enable them to be better known and understood; and (3rd) it is especially desirable that the full account of Hancock's investigations should be published together with a portion of his beautiful drawings."